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Event #1880

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ADP010797 thru ADP010815

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**Department of Defense  
Science and Technology Program  
*12th Annual SO/LIC Symposium*  
13 February 2001**

**Dr. Delores M. Etter**

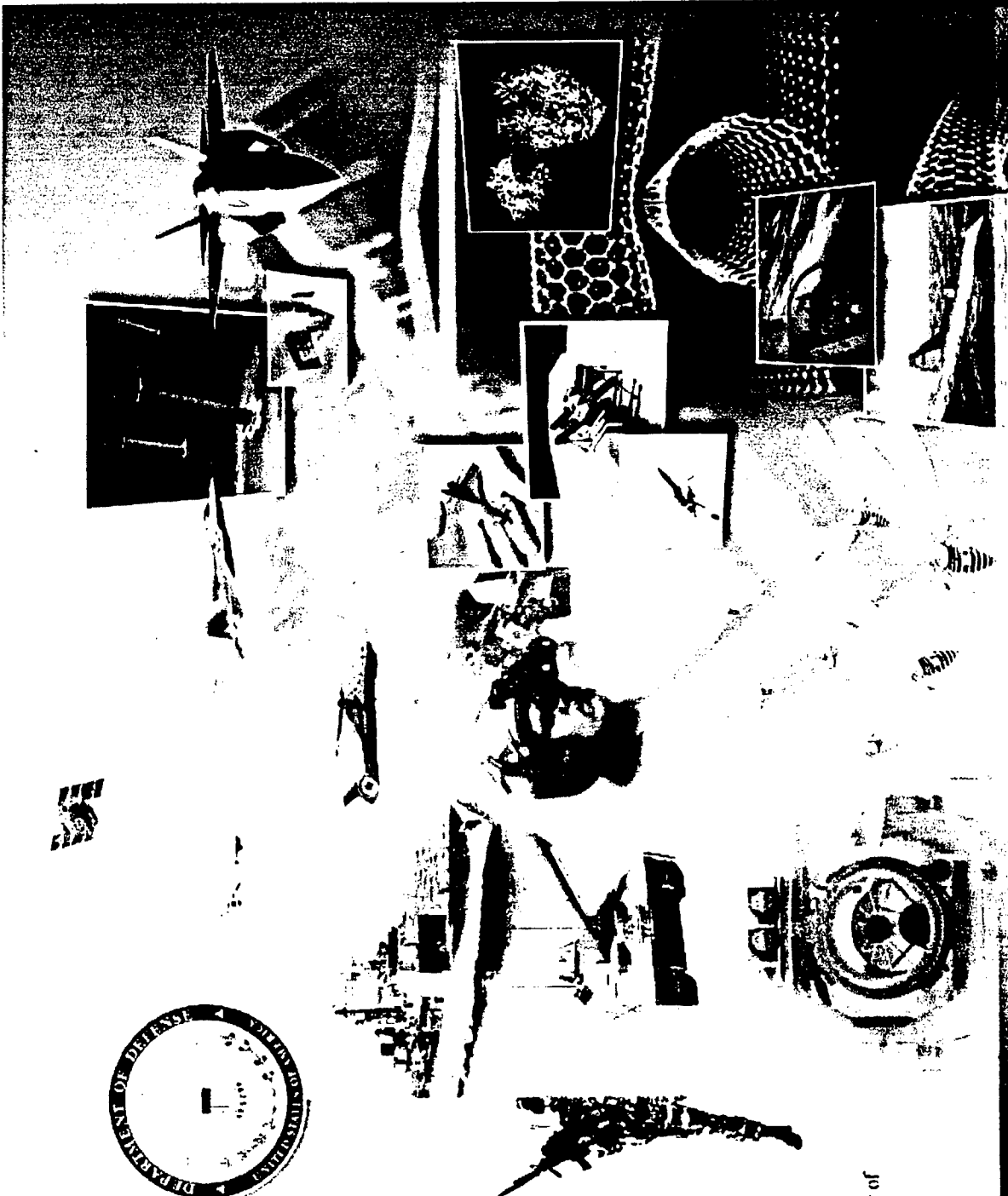
**Deputy Under Secretary of Defense (Science & Technology)**



## Mission

... to ensure  
that the warfighters  
today and tomorrow  
have superior and  
affordable technology  
to support their  
missions, and to give  
them revolutionary  
war-winning  
capabilities.

Office of the Deputy Under Secretary of  
Defense for Science and Technology



# Defense Science and Technology

# *A Focus on Revolutionary Advances*



## *Stealth*



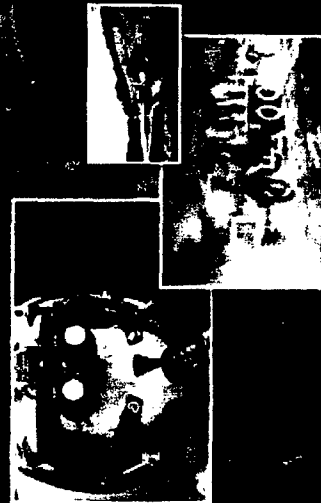
## *Adaptive Optics and Lasers*



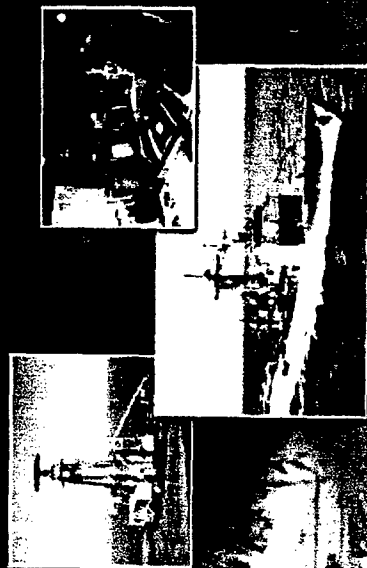
## *GPS*



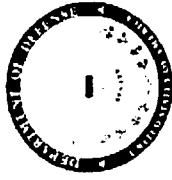
## *Night Vision*



## *Phased Array Radar*



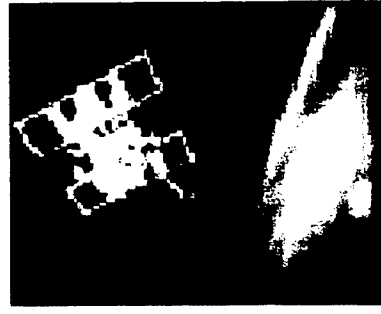
# Strategic Environment



## Global US Interests

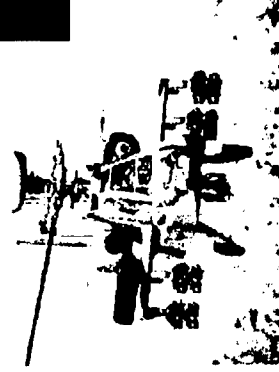
*Political - Economic - Humanitarian*

## Globalization of Technology



## Asymmetric Threats

*In any domain - Air, Land, Sea, Space or Information*



# DUSD (S&T) Priorities 2001



## *Technical*

- Basic Research
- JV 2020 Capabilities
- Revolutionary Capabilities
- Enabling Capabilities

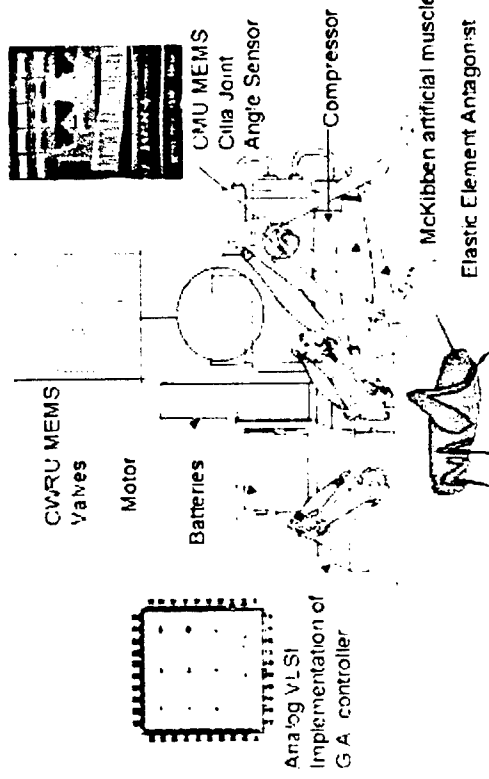
## *Non-Technical*

- Funding Stability
- Technology Transition
- S&T Workforce

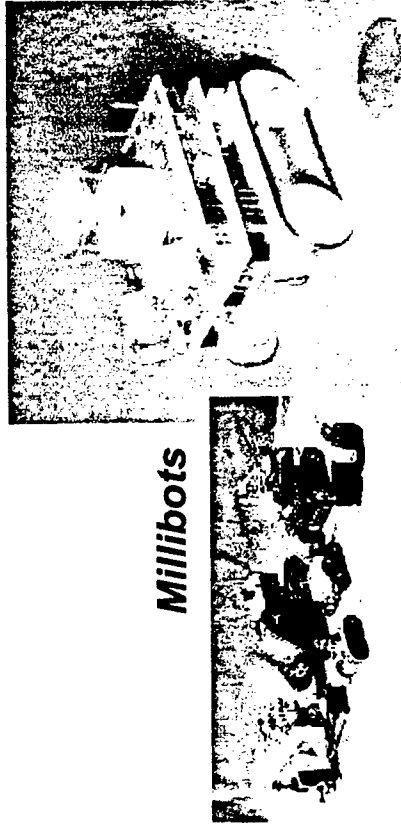
# Basic Research: Micro Robotics



**Cricket Micro-Robot**



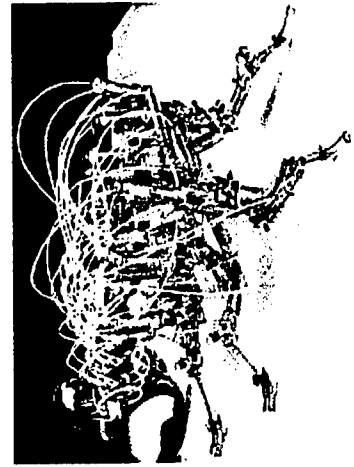
**Millibots**



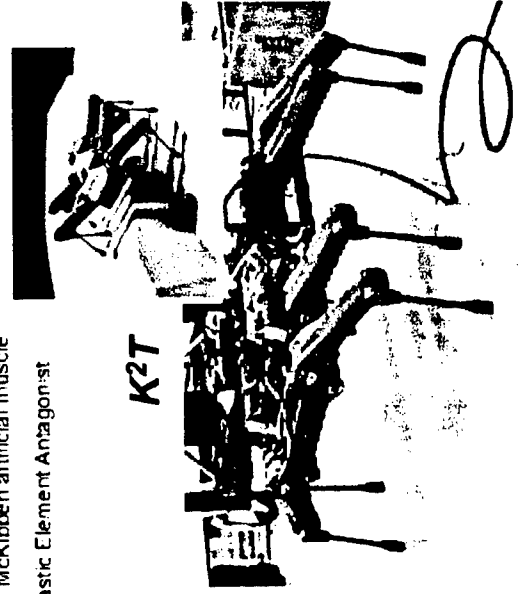
**Underwater Robotarief**



**Robot III**



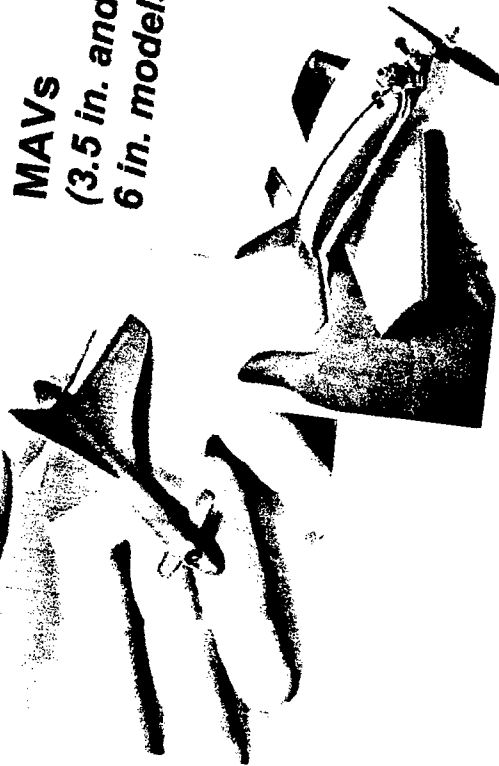
**K<sup>2</sup>T**



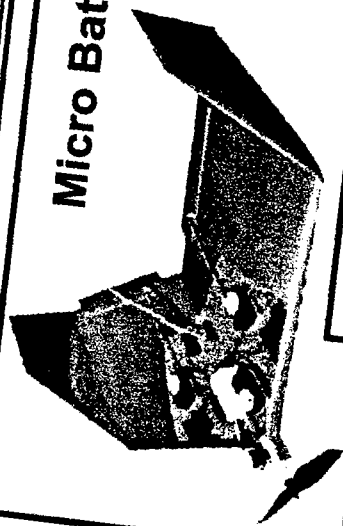
# Basic Research: Micro Air Vehicles



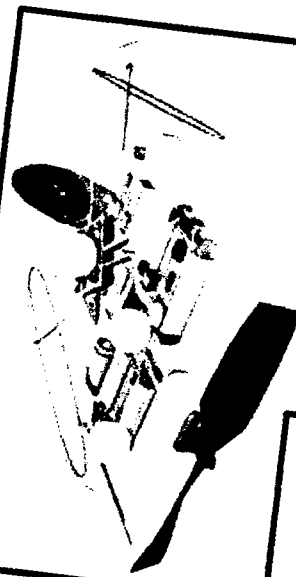
**MAVs**  
(3.5 in. and  
6 in. models)



**Micro Bat**



**Black Widow**



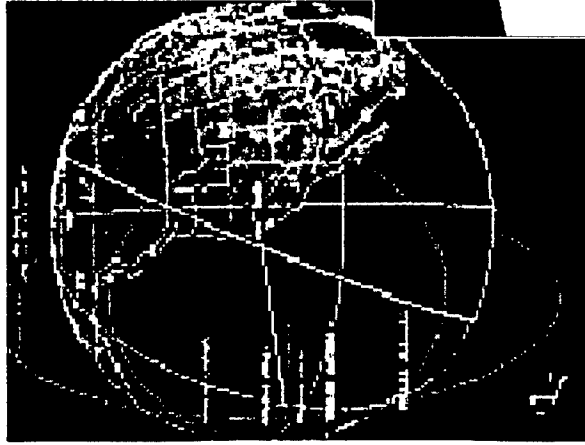
**Entomopter**



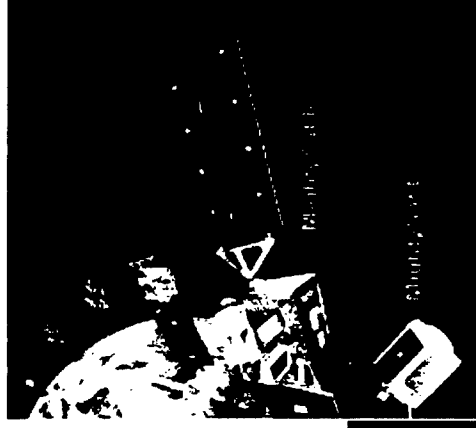
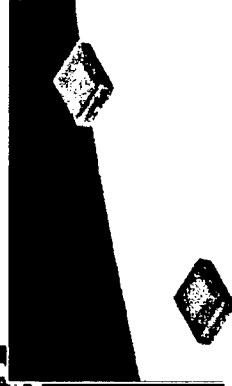
- Exoskeletal Chemical Muscle Reaction Chamber
- Exhaust Ports
- Wing Hinges
- Thermoelectric Generator
- Intensity Sensor-Actuated Trinary Steering
- Inflight, widely spread Surface Locomotors provide Anti-Roll Inertia with auxiliary fuel storage (mass) in legs/feet.
- Wing Ribs double as Gas Ducts to Circulation Control Points
- Fuel Storage and Metering is a part of Antenna Structure
- Antennas double as Trim Stabilizers



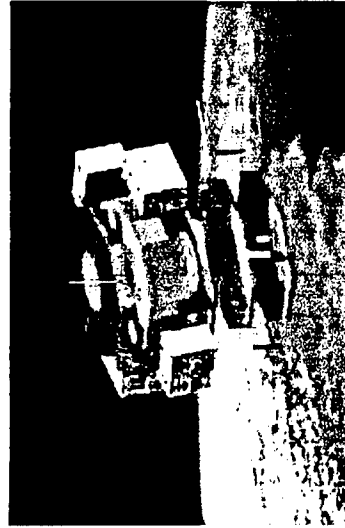
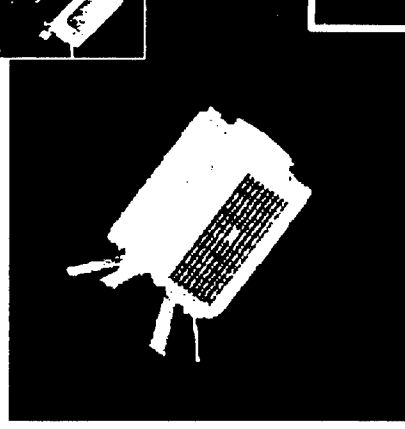
# Basic Research: Micro Satellites



**Picosatellites**  
< 2 Pounds



**Small Satellites**  
200-2000 Pounds



**Nanosatellites**  
2-20 Pounds



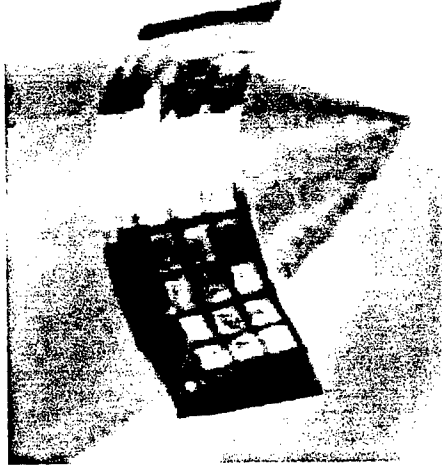
**Microsatellites**  
20-200 Pounds

# Basic Research: Smart Materials & Structures

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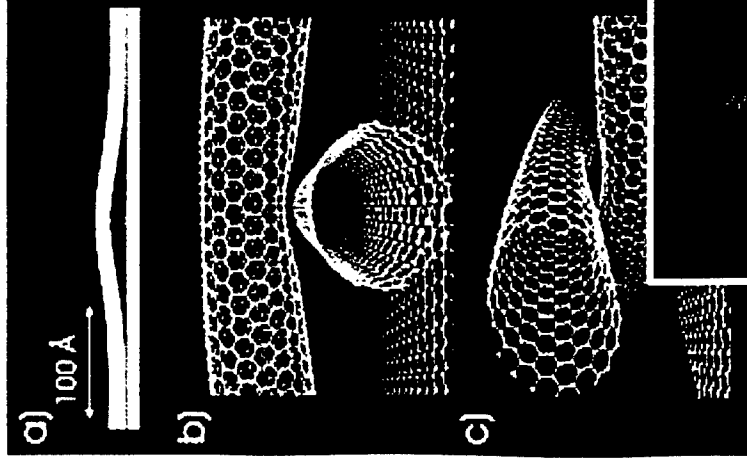
- Elastic active materials
- Smart skins and coatings
- Distributed sensors and actuators
- Armor materials by design
- Adaptive structures



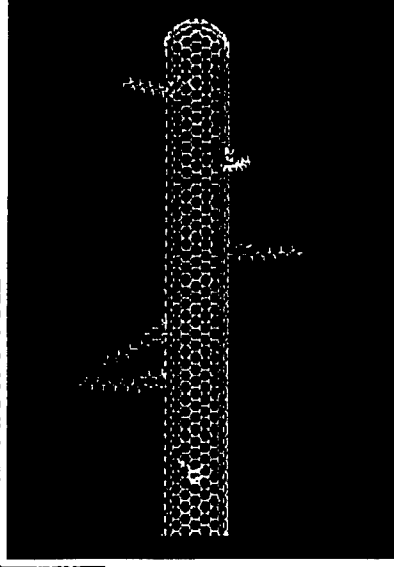
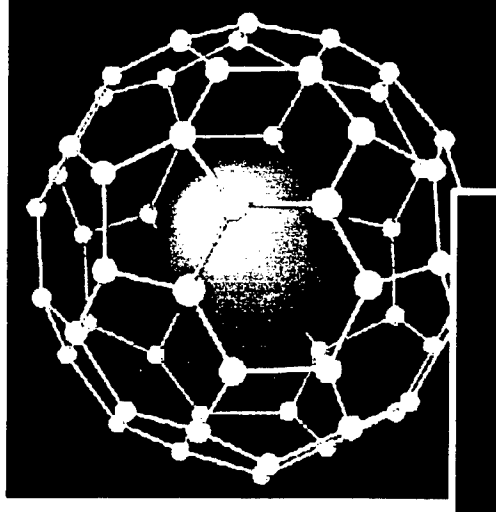
Flexible Sensor Skin

- Ultraquiet submarines,
- adaptive flight control,
- vibrational control,
- advanced stealth,
- armor materials

# Basic Research: Nanotechnology



- *Carbon Computers*
- *Molecular Engineering*
- *Nanoscale Robots, Sensors, Machines*
- *Battery Electrode and Energy Storage*
- *Vacuum Microelectronics Devices*
- *Molecular Composites*



# Multidisciplinary University Research Initiative (MURI)

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## *MURI Themes for 2002*

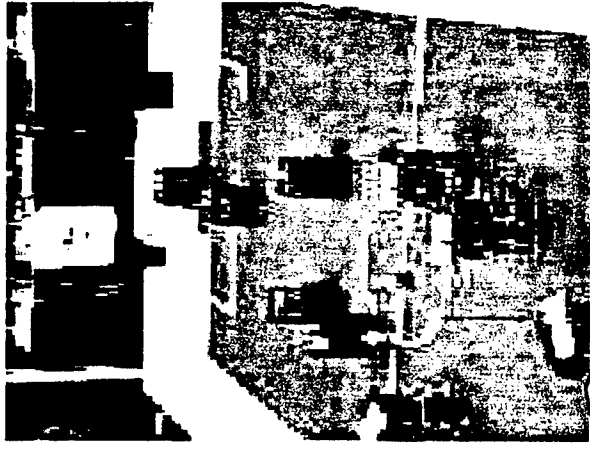
- **Energetics-** (explosives, propulsion, power)
- **Multifunction Materials-** (adaptive response to changing environments, sensors, warrior readiness, information flow)
- **Synergistic Sensing-** (battlespace awareness, combating terrorism, decision making)
- **Control for Adaptive and Cooperative Systems-** (adaptive command and control of swarms of micro air vehicles, robots, or satellite clusters)

# Collective Behavior of Smaller, Smarter Systems



## Goal: Collective Dynamic Intelligence in an Autonomous System

- Achieved By: Swarm Behavior in Low-Cost, Low-Tech Individual Entities & Cooperative Control



# Lessons From Nature



Flocking Behavior



Collective Behavior



# Collective Intelligence



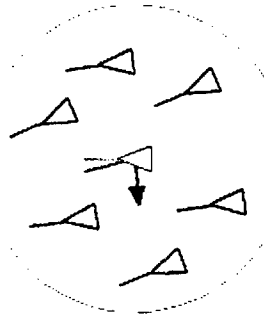
- Systems Whose Purpose is:
  - To Act in Collaboration with Other Systems
  - To Produce Information that is Greater than the Sum of the Individual Components.

# Swarm Movement

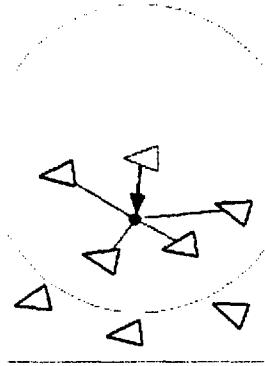


Let  $R$  be the  
desired distance  
between two  
entities.

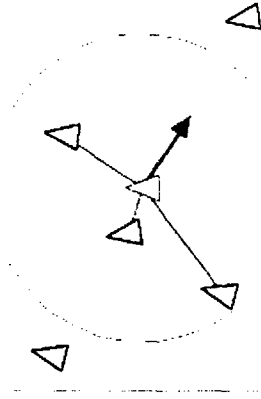
Let  $r$  be the  
actual distance  
between two  
entities.



alignment



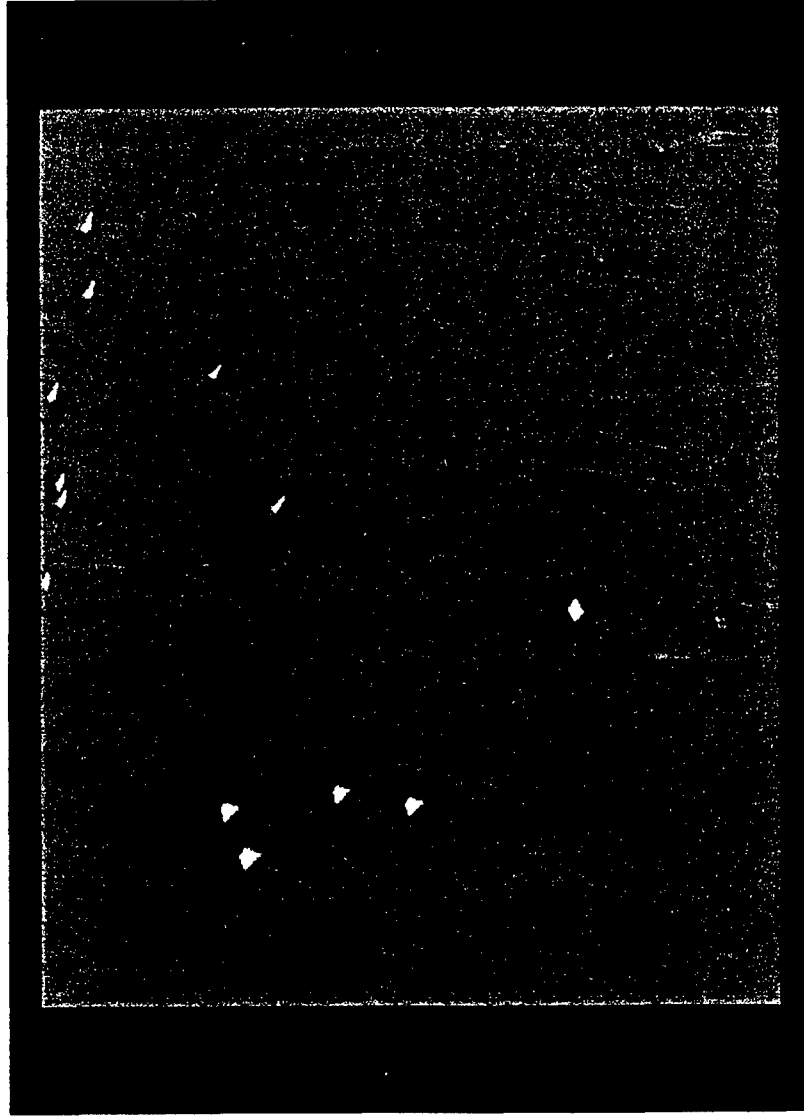
Cohesion  
( $r > R$ )



Separation  
( $r < R$ )



# Swarm Movement Model



# Simple Tasks with Collective Behavior



**Move Items to Target Location**



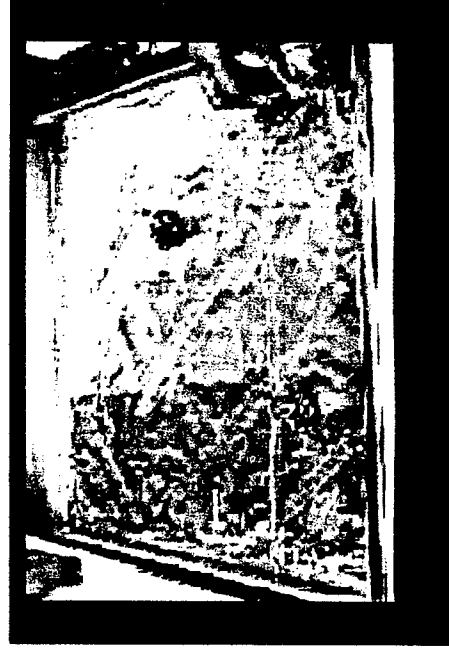
**Locate Items and Cluster Around Them**

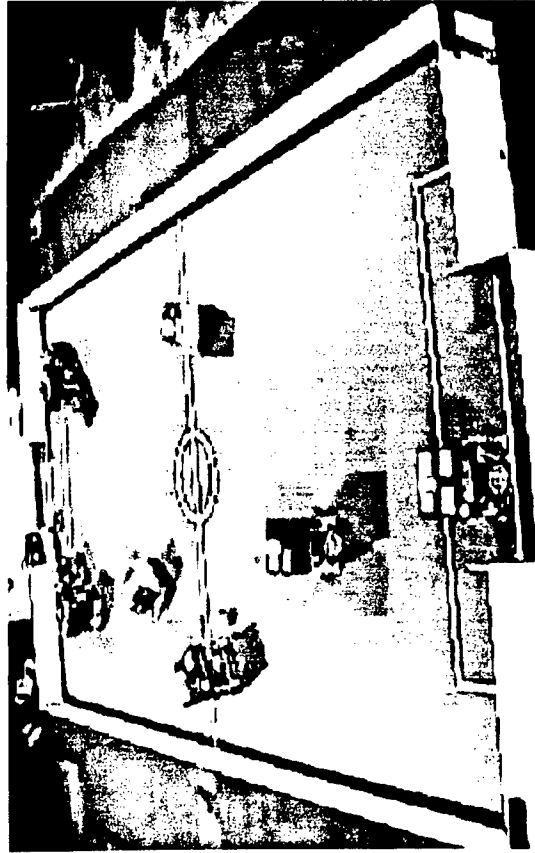


**Follow Signals, Locate and Move Items**

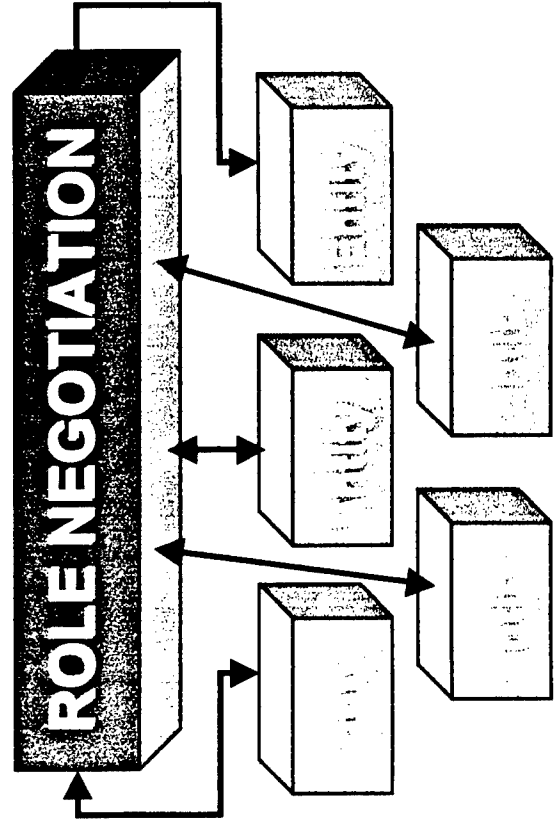
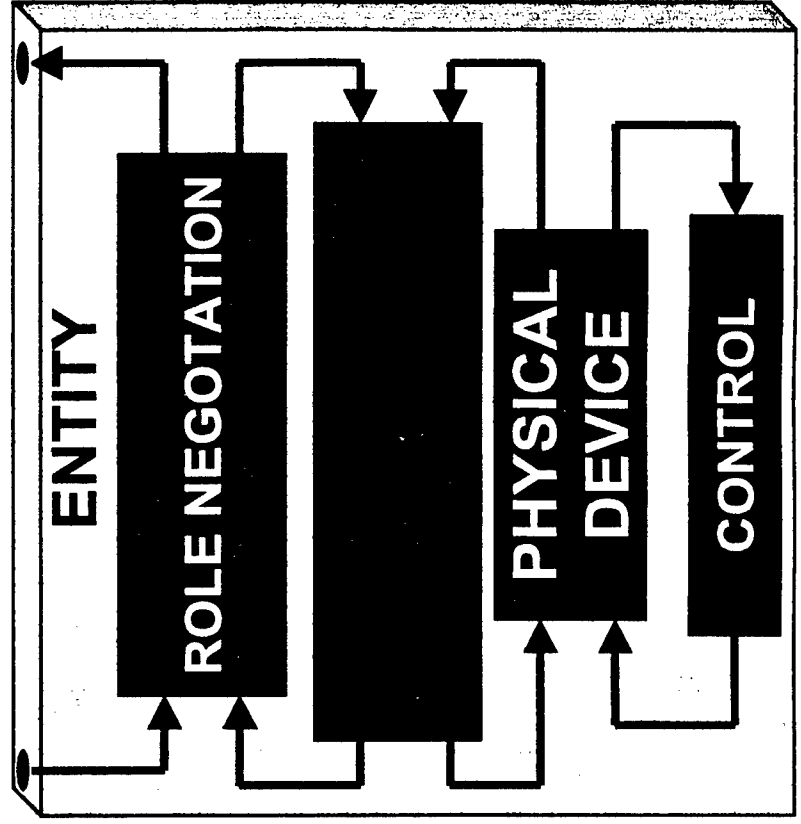


**Role Playing - Tag You're It**

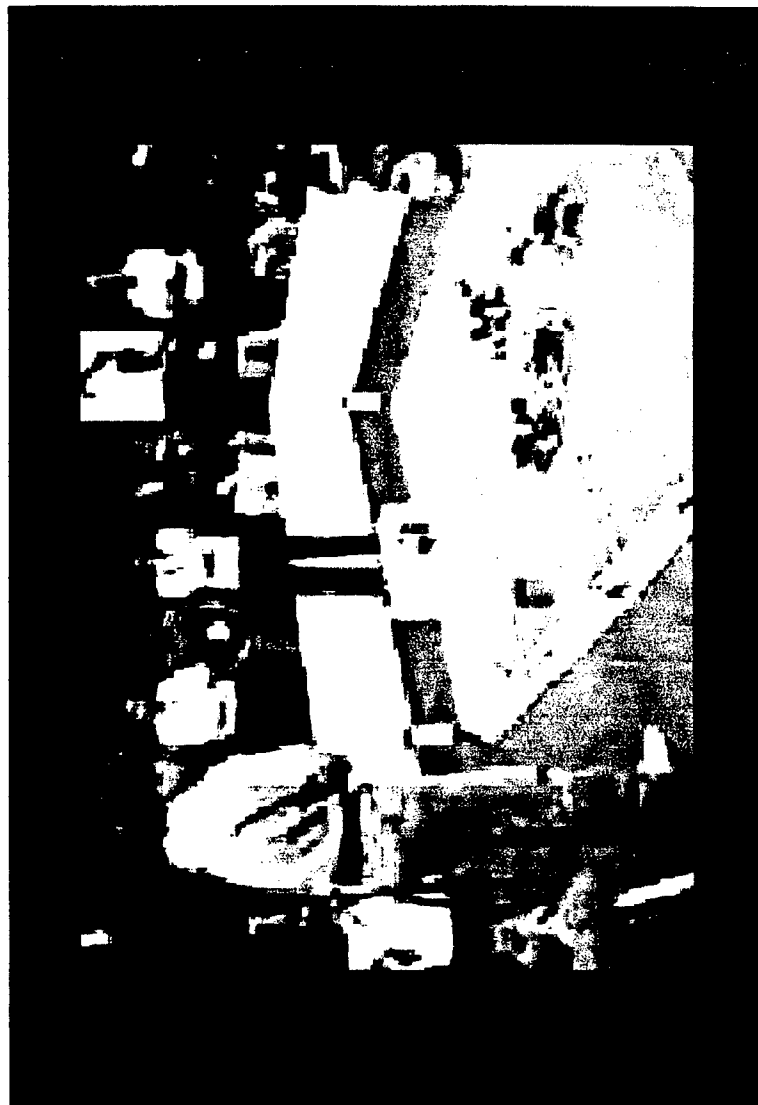




# Platform for Autonomous Control of Distributed, Multi-Entity Systems in an Adversarial, Evolving, and Uncertain Environment



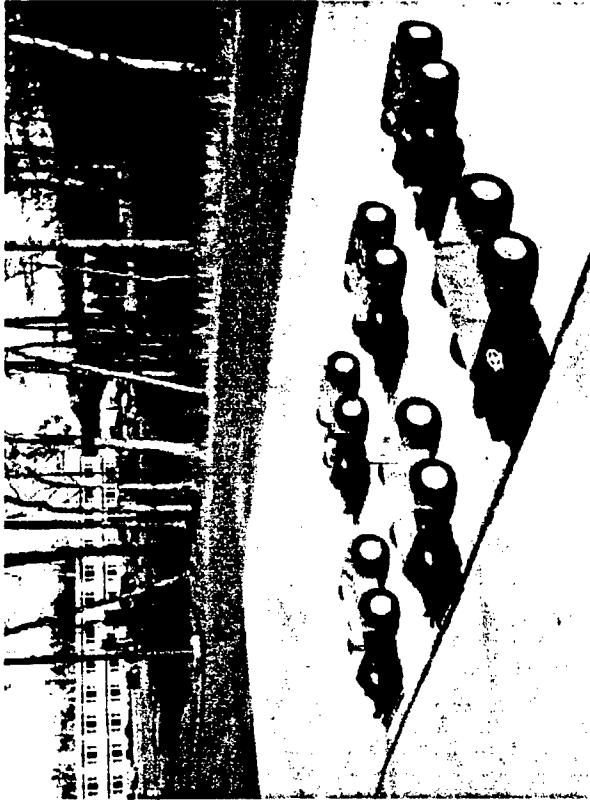
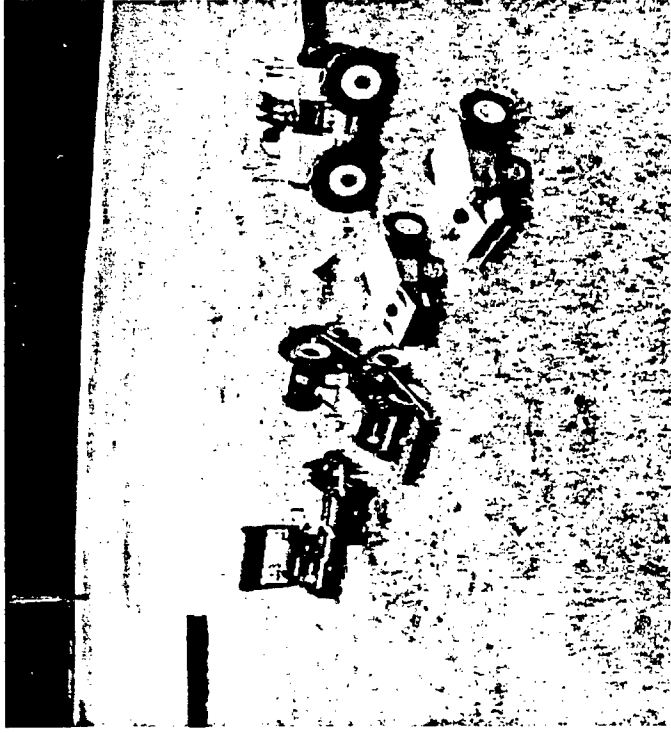
# Robocup Tournament



# Basic UXO Gathering System (Bugs)



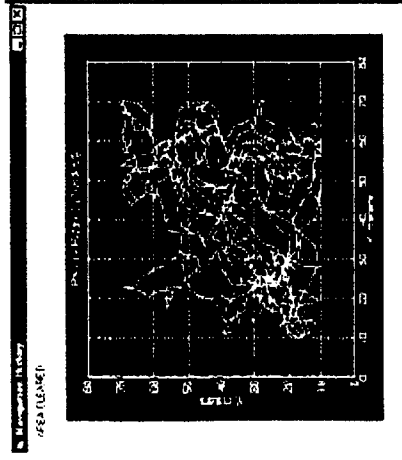
- Multiple Cooperative Behavior Robots
  - Pick Up and Carry Away Submunitions  
*Blow in Place*



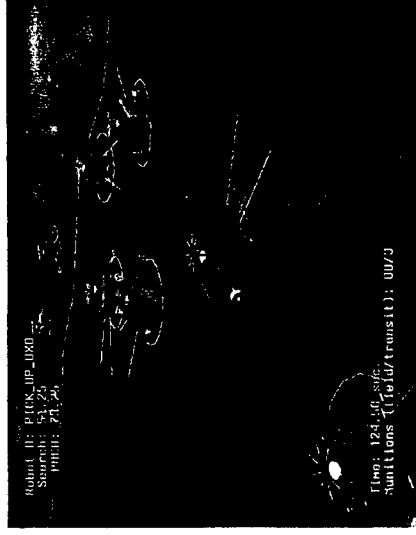
# Basic UXO Gathering System (Bugs)



- Model Search Strategies



- Simulate Systems to Optimize Subsystems



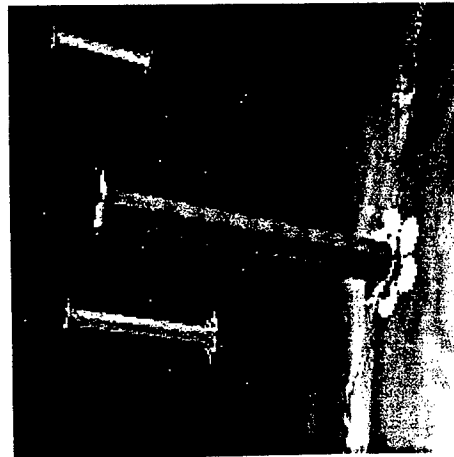
- Demonstrate Search Strategies Using Micro Robots



# BUGS In Action



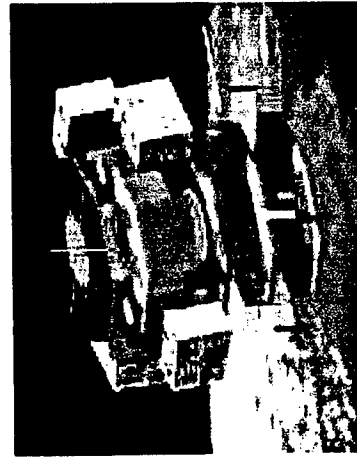
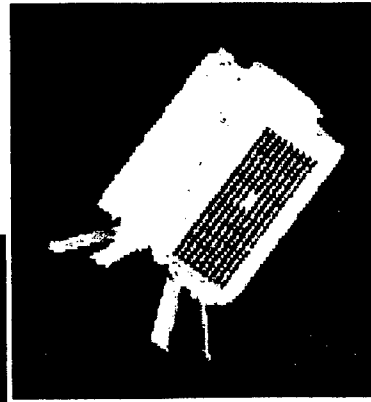
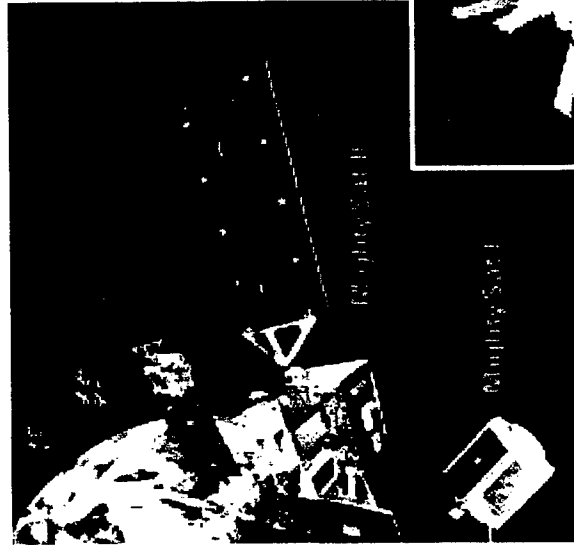
# The Future of Satellites



Microsatellites



Smallsatellites



Nanosatellites

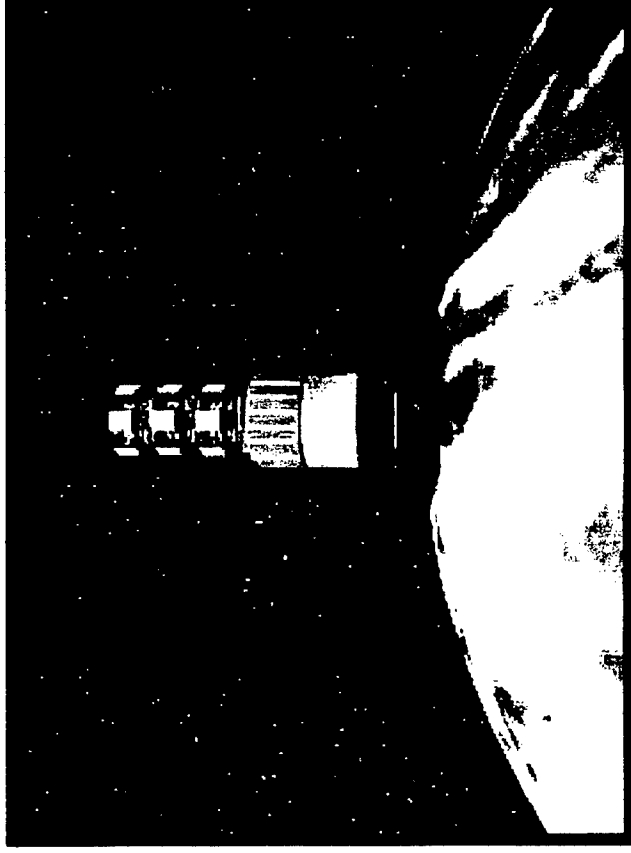


# Collaborating Microsatellite Clusters TechSat 21

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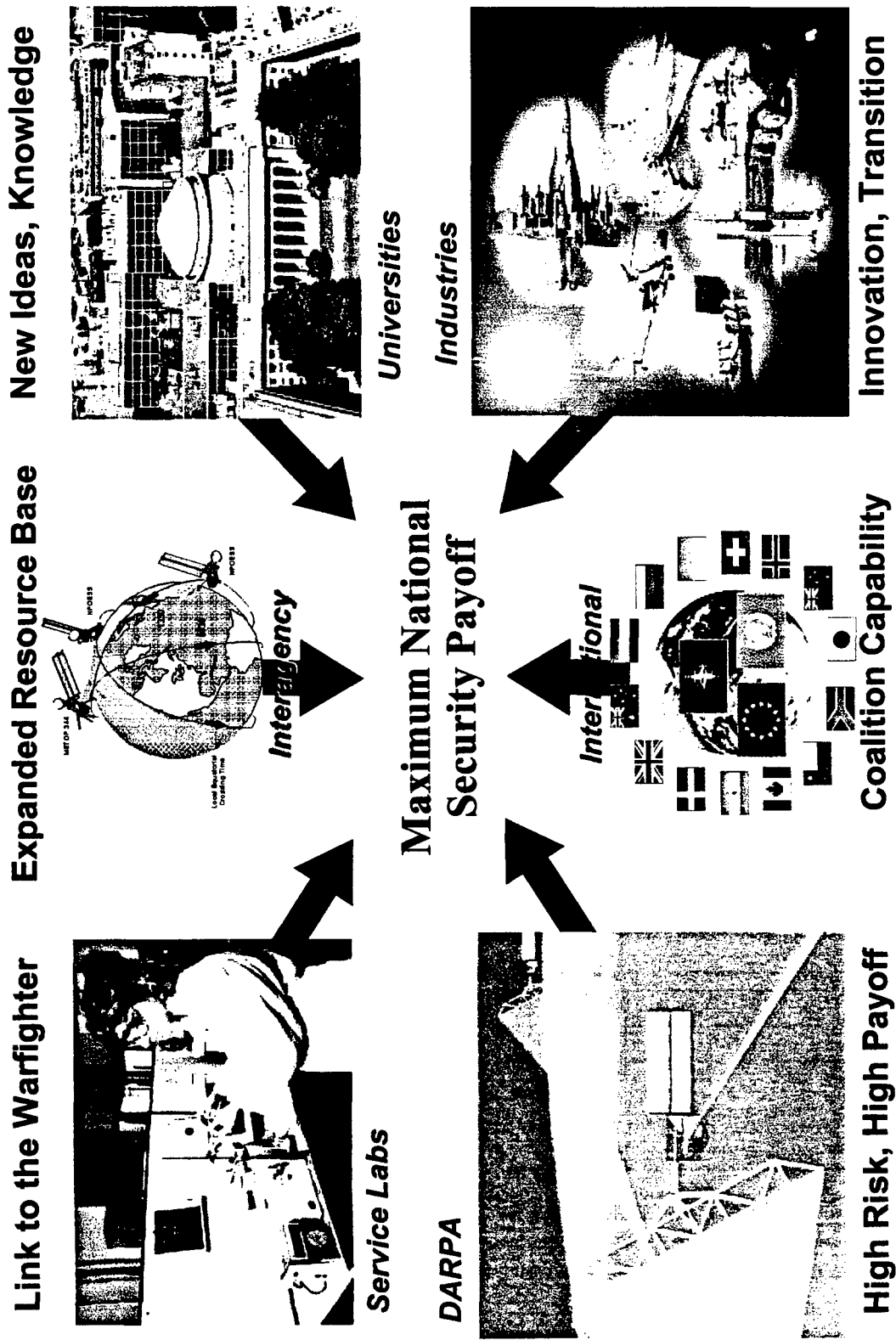


- Cluster of formation flying capable microsats form a “virtual satellite”
- Concept enables multi-mission capability
  - Space Based Radar
  - Communications
  - Geolocation



Goal: Affordable, Real-Time, On-Demand Global Awareness

# Technology Transition Requires Strong Partnerships



# A Focus on Tomorrow's Possibilities



"Technical Superiority is  
Critical for National Security.  
In peace, it provides deterrence;  
In crisis, it provides options;  
In war, it provides an edge."

Defense Science and Technology Strategy  
May 2000